Ulticom®

IMS Signaling Architecture

WHITEPAPER

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EXECUTIVE SUMMARY

The Internet Protocol (IP) Multimedia Subsystem (IMS) is a standard, IP-based communications network that provides a network-independent, common service delivery environment for both wireless and fixed network users. IMS standards define common signaling and media interfaces that are open, vendor independent, and abstract the underlying network complexities.

The progress towards IMS-based all-IP networks will be evolutionary. For the foreseeable future, IMS-based networks will coexist with traditional CS networks such as Global System for Mobile (GSM) and Public Switching Telephone Network (PSTN). Therefore, it is critical for the IMS to provide signaling gateways for interworking between SS7 protocols (e.g., Transaction Capability Application Part (TCAP)-based protocols) and SIP or Diameter. This paper describes a number of such gateways.

This paper introduces IMS network architecture, signaling interfaces, functions, and example procedures in four IMS architectural groups: IMS Core, IMS Service Delivery, IMS and Circuit-Switched (CS) Network Interworking, and IMS Charging. The IMS's nervous system is comprised of the Session Initiation Protocol (SIP) and Diameter-based signaling networks. This paper elaborates how IMS network elements interact with each other and provide signaling functions through these two key protocols.

This paper also describes how Signalware, an industry-proven, carrier-grade, highly available and scalable signaling middleware platform, supports virtually every IMS signaling network element and interface with its feature-rich SIP, Diameter, and SS7 protocol stacks. Backed with its superior platform management mechanisms, the IMS-Ready Signalware platform provides Network Equipment Providers (NEPs) with unique advantages in rapid time-to-market, fault resilience, modular scalability, portability, maintainability, and network interoperability for developing and deploying IMS elements and services.

Section 1

1.1 Introduction

This paper introduces the IMS signaling architectures, interfaces, and functions, and addresses the Signalware platform's readiness for supporting IMS signaling network elements and interfaces. The purpose of this whitepaper addresses IMS signaling networks at a reasonably technical level of detail; prior knowledge of SIP, Diameter, SS7 networks, and mobile networks will help understand the technical details.

- **Section 1** presents the purpose, audience, and scope of this paper.
- **Section 2** introduces the background of the IMS, including IMS concept and status of IMS standards and industry deployments.
- **Section 3** presents IMS signaling network architectures, interfaces, element functions, and example procedures. The IMS is divided into four architectural groups: IMS Core, IMS Service Delivery, IMS-CS Interworking, and IMS Charging.
- **Section 4** discusses a number of signaling gateways that may be needed for IMS and SS7 network interworking.
- **Section 5** addresses the IMS-Ready Signalware platform architecture and presents the benefits that the Signalware platform provides to NEPs in developing and deploying the IMS.
- **Section 6** lists standard documents and information sources referred to in this paper.
- **Appendix A** lists references used in the writing of this paper.
- **Appendix B** summarizes those IMS network elements and interfaces that Signalware supports.
- **Appendix C** lists acronyms and their corresponding descriptions.

Section 2

2. Background

2.1 IMS Concept

The IMS is a standard, IP-based communications network that presents wireless and wireline users with a variety of multimedia services, including voice, video, image, text, and data [1]. IMS-based wireless services can be classified into three categories:

- Non-real-time services such as rich media messaging and multimedia content delivery
- Near-real-time services such as Push-to-Talk over Cellular (PoC) and interactive gaming
- Real-time services such as Packet-Switched (PS) audio/video telephony and conferencing

These services may be facilitated via other generic services such as presence service and group list management service.

Fixed and mobile communication networks are converging into IMS-based all-IP networks. To meet this trend, an IMS network is defined in a horizontal architecture, which comprises three functional layers (see Figure 2-1) [2][3]. The first layer is the bearer layer, which transports signaling traffic and media streams. This layer contains switches, routers, and media-processing entities (e.g., media gateways and media servers). As it is access network-independent, an IMS can be connected to different types of existing and emerging access networks as long as they have IP connectivity. These include:

- 3rd Generation networks (3G, e.g., Universal Mobile Telecommunications System (UMTS))
- 2.5th Generation networks (2.5G, e.g., General Packet Radio Service (GPRS))
- 2nd Generation networks (2G, e.g., GSM) through gateways
- Emerging wireless IP networks such as the Wireless Local Access Network (WLAN) and the Worldwide Interoperability for Microwave Access (WiMax)
- PSTN through gateways
- Residential fixed networks such as Digital Subscriber Line (DSL) and broadband cable
- Enterprise fixed networks via IP Centrex

The second layer in the IMS architecture is the control layer, which contains signaling network elements (e.g., Call Session Control Function (CSCF), Home Subscriber Server (HSS), Media Gateway Control Function (MGCF)) for supporting common session control, media control, and access control functions through signaling protocols such as SIP, Diameter, and H.248. The control layer forms the core of the IMS, with which communications are effectively controlled for user devices attached to different types of access networks.

The third layer in the IMS architecture is the service layer, which contains Application Servers (ASs), such as SIP AS, third party Open Service Access (OSA) AS, and legacy Service Control Point (SCP). IMS conducts service control through subscribers' home networks and those signaling network elements distributed in the service layer and the control layer. This enables subscribers to receive the same types of services while they are roaming.

SInce it provides a single core network of a horizontal structure for different types of access networks and services, the IMS architecture has a clear advantage over a traditional vertical service architecture, which duplicates the same functions (e.g., session control, charging) for each type of access and service. The IMS architecture creates attractive resource sharing and cost saving opportunities for network operators and service providers.

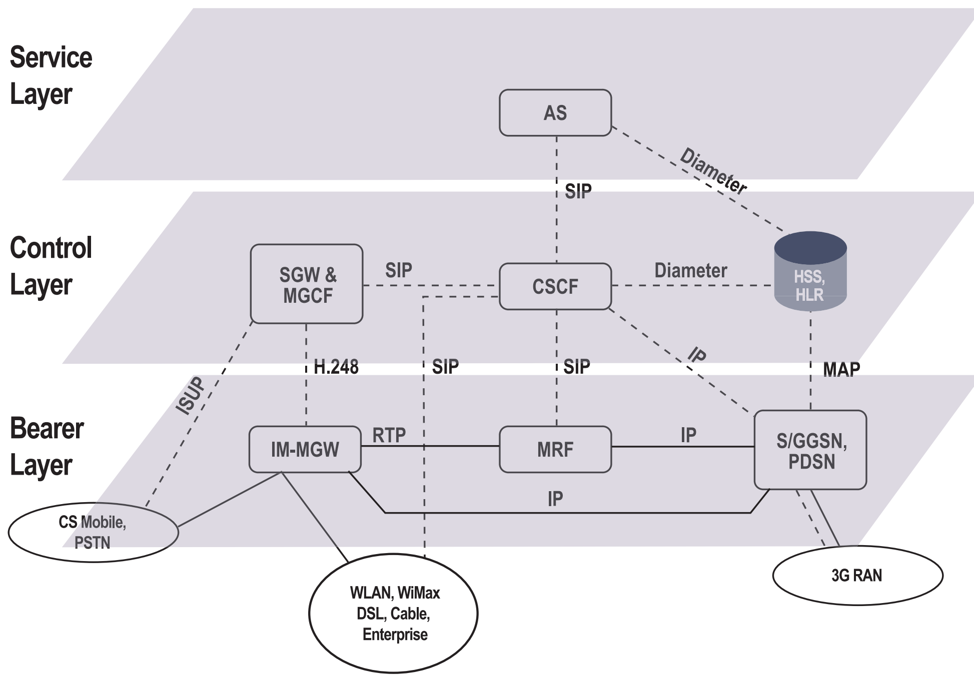


Figure 2-1 Horizontal Layered IMS Architecture

The IMS's nervous system is its signaling network, which is enabled by two key signaling protocols: SIP and Diameter. SIP is used for multimedia session setup, maintenance, and teardown [14], while Diameter is used for Authentication, Authorization, and Accounting (AAA) of user services [15]. Compared to traditional SS7 signaling protocols (which are used for CS voice service), SIP functionally corresponds to ISUP, while Diameter and its applications correspond to TCAP-based protocols. To transport IMS signaling protocols, the Stream Control Transmission Protocol (SCTP) or the Transmission Control Protocol (TCP) running on top of IPv6 is used. Most early IMS networks use SCTP as the preferred reliable protocol. During the transition period, IPv4 may be used in the initial IMS deployment as well [13]. One critical issue to the IMS is security, which can be ensured via the mandatory network layer security (i.e., IP Security or IPsec), via the optional Transport Layer Security (TLS), and via the application layer security (e.g., the Hyper Text Transfer Protocol (HTTP) Digest Authentication for SIP).

2.2 IMS Standards

A number of standards organizations are contributing directly or indirectly to the development of IMS standards. The Third Generation Partnership Project (3GPP) is the main organization responsible for developing the standards, including architecture, interfaces, network element functions, and procedures [1][2]. Initially defined for GPRS and UMTS networks, IMS standards are largely reused by 3GPP2 for defining the Multimedia Domain (MMD) in Code Division Multiple Access 2000 (CDMA2000) networks [11]. Moreover, the IMS is being adopted by the European Telecommunications Standards Institute (ETSI) as the standard SIP-based architecture for wireline multimedia service networks [12].

The 3GPP specifies an IMS network and service infrastructure, while the underlying IP-based protocols such as SIP and Diameter are defined in the IETF. The service specifications, such as PoC, are generated in the Open Mobile Alliance (OMA). Both the 3GPP and the OMA have made private extensions to IETF protocols used in the IMS (e.g., P-headers in SIP, Attribute-Value-Pairs (AVPs) in Diameter applications). While the major parts of the IMS standards have been established through two phases of 3GPP specification development (Release 5 and Release 6), continuous efforts are being made towards their completeness and maturity.

Section 2

Although the IMS was originally specified for 3G mobile networks, it indeed provides ideal common service deployment infrastructure for all-IP wireline and wireless networks.

Migration to all-IP based network services will be an evolutionary process. Initial IMS deployments include non-real-time services (e.g., multimedia content delivery) and near-real-time services (e.g., PoC). Due to limited deployment of high bandwidth radio access networks, IMS-based real-time services (e.g., Voice over IP (VoIP), video call) are not yet available in the mass market. Early IMS network operators plan to provide a comprehensive suite of multimedia services using WLAN for hotspot areas and plan to provide non- or near-real-time services using existing PS networks for large mobility areas. In addition, carriers are planning to offer hosted services (e.g., unified messaging, Virtual Private Network (VPN), and ad hoc conferencing) through IMS to large corporate enterprise networks.

Network operators have already made significant investments in 2G and 2.5G networks. To maximize the usage of existing networks, they would prefer an incremental approach when adding new network subsystems into IMS-based, converged networks. To realize the benefits of IMS, they must deploy gateways to support interworking between different types of signaling and media networks.

Section 3

3. IMS Signaling Architecture

Like SS7 signaling networks in traditional CS networks, SIP and Diameter-based signaling networks provide the IMS fundamental signaling functions for session and service control. IMS signaling network elements reside in the control and service layers, and can be divided into the following four architectural groups, each of which has specified roles [2][3][4]:

- **IMS Core architecture**, which routes SIP messages, control multimedia sessions, and accesses/stores subscriber information. It resides in the network control layer and interacts with the other three groups.
- **IMS Service Delivery architecture**, which provides enhanced IMS services and mobile IN-like services. It resides in the service layer and interacts with the IMS Core network.
- **IMS-CS interworking architecture**, which supports signaling protocol interworking between IMS and CS networks. It resides in the network control layer and interacts with the bearer layer.
- **IMS charging architecture**, which provides offline and online charging functions for IMS services. It resides in the service layer and interacts with network elements in the control layer as well as in the service layer.

The following subsections elaborate signaling system architectures and functions residing in these four groups.

3.1 IMS Core Architecture

The IMS Core architecture is a SIP and Diameter-based signaling network [2][14][15]. It is comprised of three types of SIP proxy servers or CSCFs: Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), and Serving-CSCF (S-CSCF). The IMS core also includes two types of Diameter servers: a Home Subscriber Server (HSS) for storing subscriber data and a Subscription Locator Function (SLF) for storing HSS addresses. Figure 3-1 shows the IMS Core architecture. Note that in this figure (and in the subsequent figures), a label outside the parentheses indicates an interface name, while a label inside the parentheses indicates the protocol used for this interface.

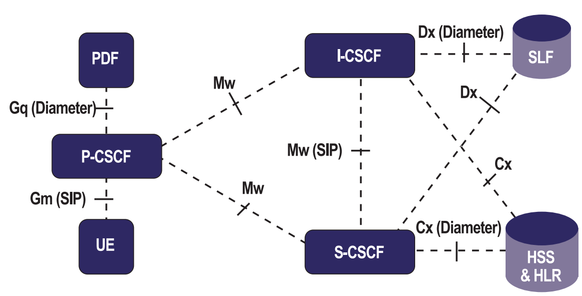


Figure 3-1 IMS Core Architecture

The P-CSCF is the first contact point within an IMS Core. It maintains a security association between itself and each User Equipment (UE) using IPsec, performs SIP (de)compression using the Signaling Compression (SigComp) mechanism [18], and provides information to a Policy Decision Function (PDF) for resource authorization and Quality of Service (QoS) control. The P-CSCF also relays SIP messages between UEs and I/S-CSCFs. Note that the PDF, which is not shown in the figure, may be part of the P-CSCF or a standalone entity. It interacts with the P-CSCF via the Diameter-based Gq interface and with the Gateway GPRS Support Node (GGSN) via the Common Open Policy Service (COPS) protocol-based Go interface.

The I-CSCF is an optional contact point within an operator's network for all connections destined for a user of that network operator. It forwards SIP messages to one of the S-CSCFs, which is selected according to

information queried from an HSS through the Diameter-based Cx interface. If multiple HSSs are deployed in the IMS Core, the I-CSCF needs to first contact the SLF through the Diameter-based Dx interface, in order to get the address of an HSS for serving the user. (NOTE: The SLF is a Diameter Redirect Agent and can be optional.) The I-CSCF can be used to hide the configuration, capacity, and topology of the network from the outside.

The S-CSCF is the pivotal element in the IMS and performs session control and registration services for home subscribers. It may serve as a SIP proxy to relay SIP messages, as a SIP User Agent (UA) to initiate or terminate SIP transactions, and as a SIP registrar to authenticate users during their registrations. The S-CSCF retrieves subscriber information (e.g., authentication vector, user profile) and gets notified of subscriber information change from the HSS through the Cx interface.

The IMS supports roaming services via a P-CSCF in a roamer's visited network, which routes SIP messages to the roamer's S-CSCF in the home network. Both the S-CSCF and the P-CSCF maintain session timers (i.e., they are stateful proxies). All the CSCFs generate Charging Data Records (CDRs). Depending on deployment needs, these three types of CSCFs may be distributed into three different physical entities or may be consolidated into one or two entities.

The HSS is a stateless Diameter server, which stores subscribers' profiles (e.g., user identities), registration (e.g., location and authentication parameters), and service logic information (e.g., filtering criteria and trigger points) information. It may also support Home Location Register/Authentication Center (HLR/AuC) functionality and Mobile Application Part (MAP)-based interfaces for legacy 2G and 2.5G networks. Subscriber data stored in the HSS is the key enabler for service mobility across different types of access networks and user roaming between different network operators.

To describe SIP and Diameter-based signaling procedures in the IMS Core, two examples are given below. The first example shows an initial registration procedure (see Figure 3-2) [5], which assumes the user roams to a visited network. This procedure starts with the user's SIP REGISTER request being sent to the visited P-CSCF. Due to air interface bandwidth limitation, messages are compressed before being sent out by the user and are decompressed at the P-CSCF. If multiple S-CSCFs exist in the user's home network, an I-CSCF needs to be deployed for selecting an S-CSCF for serving the user session. In this case, the P-CSCF resolves the address of the user's home I-CSCF using the user's home domain name and forwards the REGISTER to the I-CSCF. After the I-CSCF sends a User-Authorization-Request (UAR) to the HSS, which returns available S-CSCF addresses, the I-CSCF selects one S-CSCF and forwards the

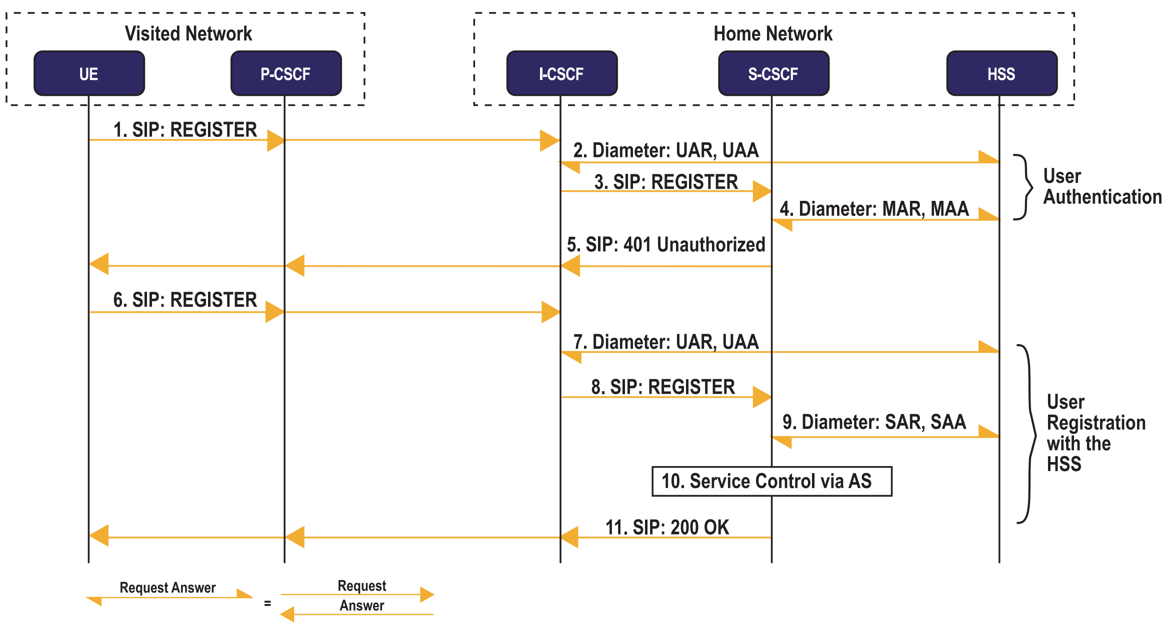


Figure 3-2 Signaling Message Flow of Registration

REGISTER message. Upon receipt of the REGISTER, the S-CSCF retrieves authentication vectors from the HSS via a Diameter Multimedia-Authentication-Request (MAR) and then returns to the user a SIP 401 Unauthorized message which carries the authentication challenge data. After computing an authentication response, the user sends to the S-CSCF another REGISTER message carrying the challenge response. The S-CSCF verifies the response and if it is correct, downloads the subscriber profile from the HSS via a Diameter Server-Assignment-Request (SAR). The S-CSCF may then contact an AS for service control as specified in the subscriber profile, before returning a 200 OK message to the user.

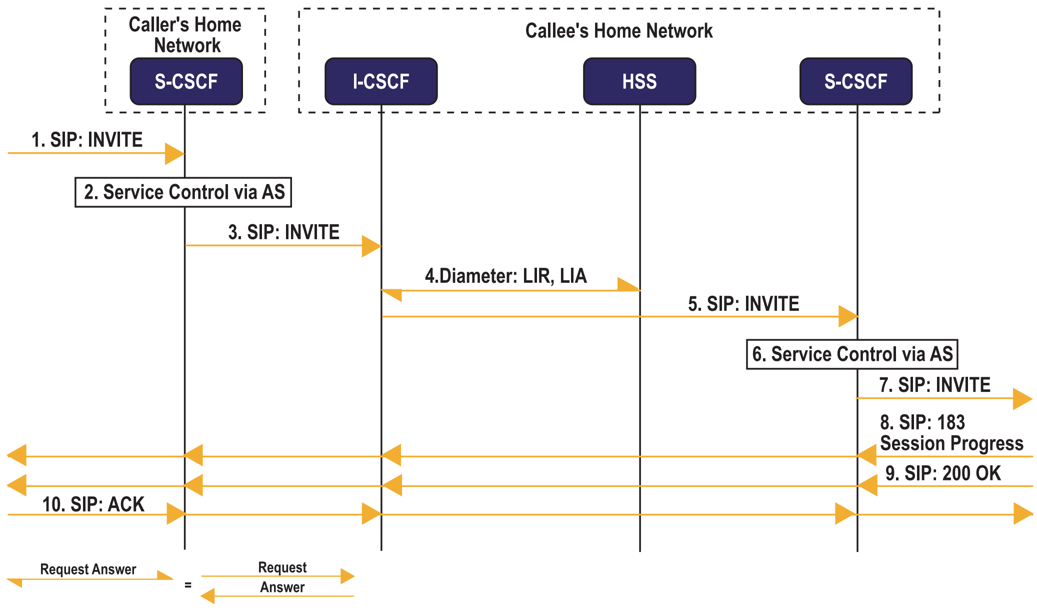


Figure 3-3 Signaling Message Flow of Session Setup

The second example shows a signaling flow for a session setup between two IMS users (see Figure 3-3) [2][5], assuming multiple S-CSCFs are deployed. A session setup procedure is a process of discovering network elements and signaling paths. When routing the INVITE message, the callee's I-CSCF interrogates the callee's HSS for the address of an assigned S-CSCF via a Diameter Location-Info-Request (LIR). The HSS responds with a Diameter Location-Info-Answer (LIA). Before forwarding the INVITE message, the caller's and the callee's serving S-CSCFs may interact with application servers for service control according to the service logic downloaded during user registration. Address resolution and standard SIP routing mechanisms are used to route the INVITE message from the caller's UE all the way to the callee's UE. The discovered path is caller's UE® caller's visited P-CSCF® caller's serving S-CSCF® callee's I-CSCF® callee's serving S-CSCF® callee's visited P-CSCF® callee's UE. The messages returned from the callee's UE (e.g., 183 Session Progress) follow the reverse path. Note that an offer-answer-based session negotiation procedure is also conducted in the meantime. This is achieved via the Session Description Protocol (SDP) carried in SIP message bodies (e.g., INVITE with an offer and 200 OK with an answer) [6].

3.2 IMS Service Delivery Architecture

The IMS provides enhanced, value-added IM services via the IMS Service Delivery network, which comprises S-CSCF, AS, Media Resource Function (MRF), and HSS. Figure 3-4 illustrates the network architecture [2], where the S-CSCF acts as the central session control point, the ASs and the MRF are service execution points.

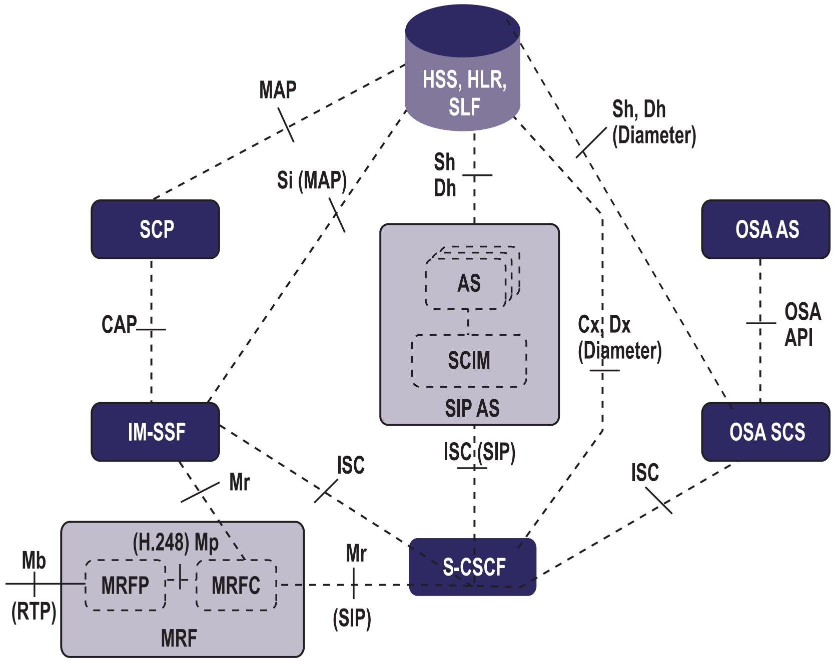


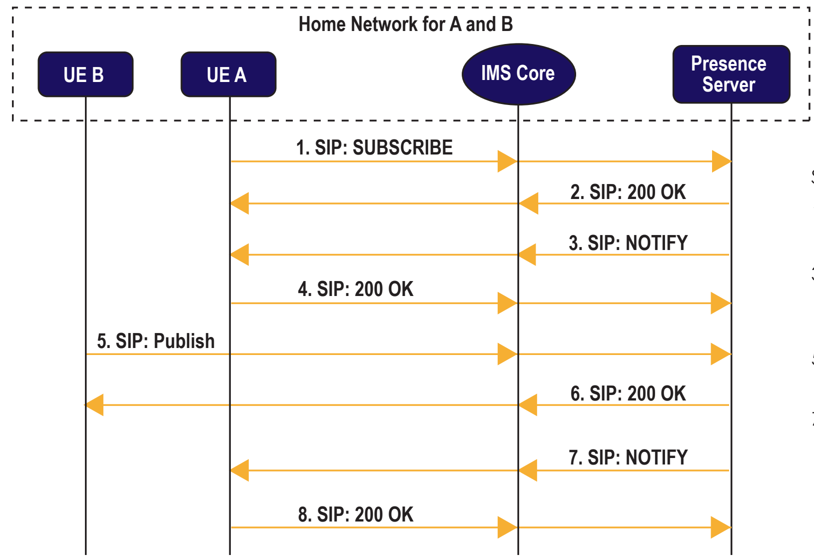
Figure 3-4 IMS Service Delivery Architecture

The IMS conducts home network-based service control. That is, a subscriber's S-CSCF interacts with service platforms through the SIP-based, intra-operator interface, named the IMS Service Control (ISC). To control dynamic behaviors of the ISC interface, both the S-CSCF and the AS maintain transaction state models for each incoming leg and each outgoing leg. The S-CSCF also maintains session state models for incoming and outgoing legs towards other SIP session control entities (e.g., another S-CSCF).

To perform a service logic control for a subscriber, the S-CSCF checks received SIP requests (e.g., INVITE) against eXtensible Markup Language (XML)-encoded service trigger points (filter criteria), which are part of the subscriber's service profile retrieved from the HSS during user registration. The information that is checked includes SIP method type, headers, Request-URI, and session description. If a trigger point is met, the S-CSCF will select an AS and route the SIP request to the AS in which the service is executed.

In the IMS, the following three types of service delivery platforms interface with the S-CSCF via the ISC:

- OSA AS, which resides in another network domain and interacts with the S-CSCF through an OSA Service Capability Server (SCS). With a standard OSA API, the SCS gateway ensures that the third-party AS can securely provide value-added services to home network subscribers.
- Legacy SCP, which resides in an SS7 network and interacts with the S-CSCF through an IM Service Switching Function (IM-SSF). Leveraging legacy Customized Applications for Mobile network Enhanced Logic (CAMEL) infrastructure and the IM-SSF, IMS network operators are able to cost-effectively provide IMS users with existing mobile IN services (e.g., prepaid service control).
- SIP AS, which resides in the home network and provides SIP-based services (e.g., presence, instant messaging). Depending on whether an AS originates, terminates, or relays SIP dialogs, a SIP AS may act as a UA, a Back-To-Back UA (B2BUA), or a proxy server. As an example, Figure 3-5 shows a message flow for a presence server-related procedure, where user A subscribes to the presence information of user B, and the presence server acts as a UA.



Steps:

1-2: A subscribes for B's presence info.

3-4: The presence server notifies A of B's current availability.

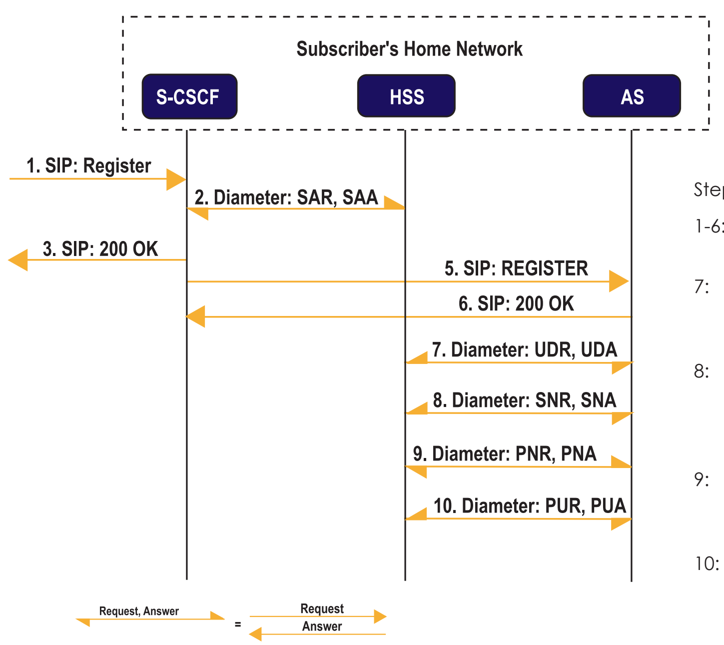
5-6: B changes his availability status

7-8: The presence server notifies A of B's updated availability.

Figure 3-5 Message Flow of User A Subscribing to Presence Information of User B

Besides interfacing with the S-CSCF, these three types of application servers also interface with the HSS. Three types of interactions exist between the HSS and the various ASs, as shown in Figure 3-4.

1. The SIP AS and the OSA SCS may obtain subscribers' data (e.g., location information) actively (pull) or passively (push) from the HSS through the Diameter-based Sh interface in a similar fashion to the S-CSCF. Figure 3-6, which is self-explanatory, illustrates a message flow for interactions between an AS and an HSS through this interface.
2. If multiple HSSs are deployed then in a manner similar to an I-CSCF contacting an SLF via the Dx interface, an AS may obtain HSS addresses from the SLF via the Diameter-based Dh interface before contacting an HSS.
3. In order to arm those trigger points in the call state models, the IM-SSF downloads the subscriber's service profile from the HSS/HLR through the MAP-based Si interface.



Steps:

1-6: A user is registered and the AS is informed of user registration.

7: The AS requests subscriber data via User-Data-Request (UDR) and receives data in UDA.

8: The AS subscribes for notification of user data changes in the HSS using Subscriber-Notification-Request (SNR) and gets confirmation in SNA.

9: Upon user data change in the HSS, the AS gets notified via Push-Notification-Request (PNR) and responds with PNA.

10: The AS updates user data in the HSS using Profile-Update-Request (PUR) and gets confirmation in PUA.

Figure 3-6 Message Flow of AS Interacting with HSS via Sh Interface

In addition to application servers, the IMS defines a special type of Media Resource Function, or MRF, which interacts with the S-CSCF and supports interactive media services such as announcement, PoC, and conferencing. An MRF comprises an MRF Controller (MRFC) and a MRF Processor (MRFP) with the former controlling the latter for media processing via the H.248 protocol. The MRFC is a SIP UA and interfaces with the S-CSCF using the Mr interface. When an MRF provides a media service, another AS may be used to support supplementary services for the MRF (e.g., conference booking) through the S-CSCF. As an example, Figure 3-7 depicts a PoC session setup procedure for a one-to-one conversation, assuming the inviting user and the invited user have the same home network and are currently in their home network [13]. Upon completion of this procedure, both the inviting UE and the invited UE establish sessions with the PoC server (i.e., the MRF).

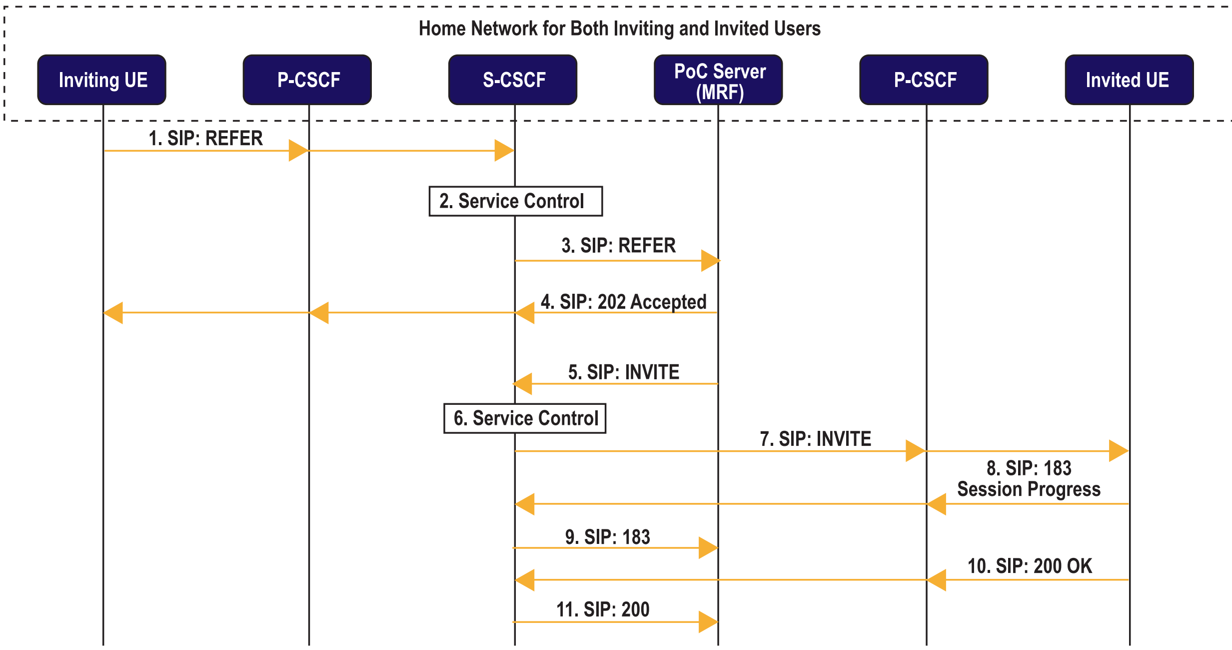


Figure 3-7 PoC Session Setup Signaling Flow for a One-To-One Conversation

3.3 IMS-CS Interworking Architecture

Traditional CS (e.g., PSTN, GSM) voice service will coexist with PS multimedia services for the foreseeable future. Therefore, it is critical to provide interworking between IMS and CS-based voice services. To this end, the IMS provides a distributed softswitching architecture (see Figure 3-8), which comprises the following network elements [2]:

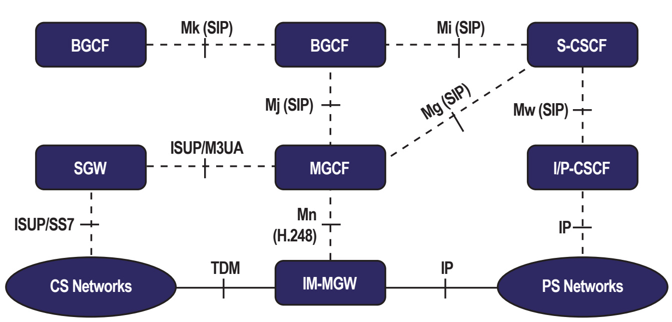


Figure 3-8 IMS-CS Interworking Architecture

- **Signaling Gateway (SGW)**, which converts the transport of the ISDN User Part (ISUP) protocol between Message Transfer Part 3 (MTP3) and MTP3 User Adaptation (M3UA).
- **IM Media Gateway (IM-MGW)**, which converts media format provided in one type of network to the format required in another type of network (e.g., from the Time Division Multiplexing (TDM)-based format to the IP-based format).
- **Media Gateway Control Function (MGCF)**, which acts as a SIP UA and translates signaling messages between SIP and ISUP. It also controls the media conversion in one or multiple IM-MGWs using the media gateway control protocol, H.248, according to received ISUP or SIP messages.
- **Breakout Gateway Control Function (BGCF)**, which determines where the interworking should occur when a session is originated from an IMS user. If the interworking occurs in the same network, the BGCF will select an MGCF; otherwise, it contacts a BGCF belonging to another network (operator), where the interworking will take place.

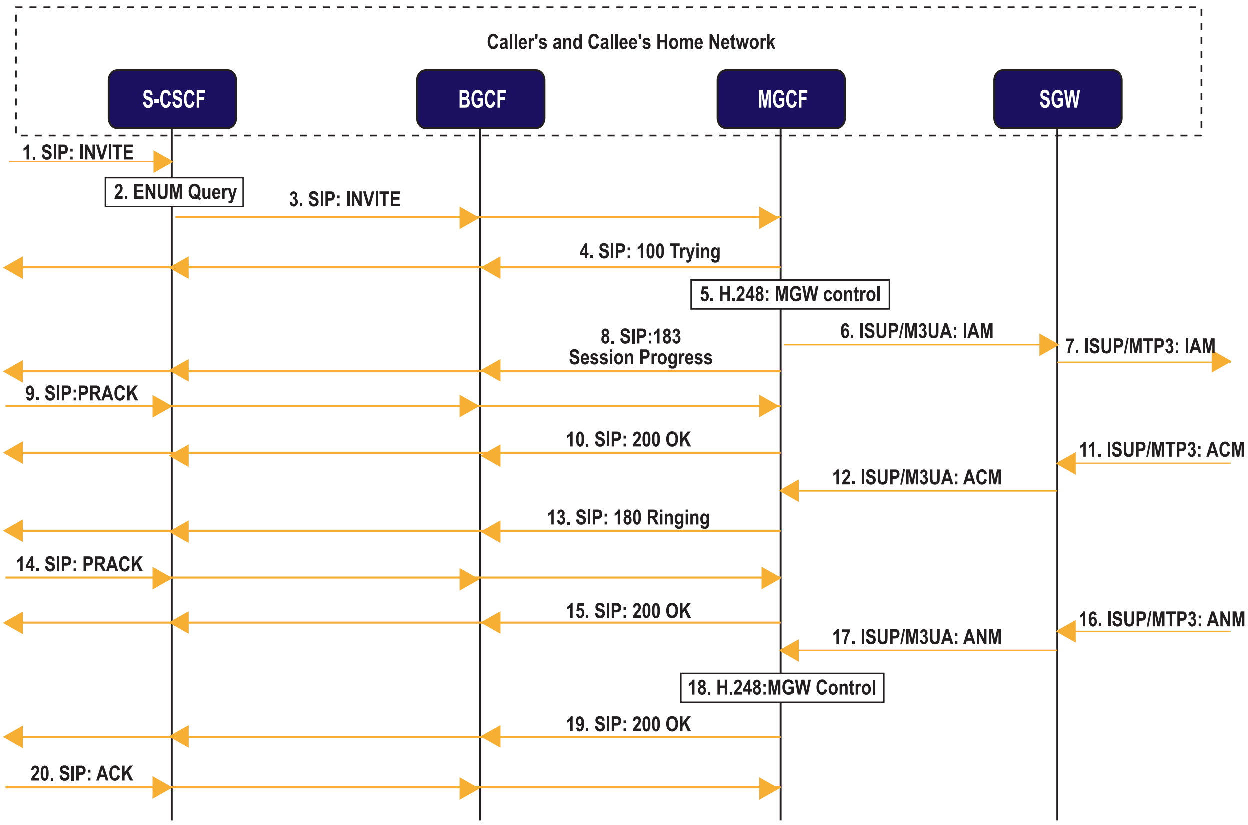


Figure 3-9 Call Setup Message Flow with an IMS User Calling a CS User

As an example, a session setup signaling flow with an IMS user calling a CS user is illustrated in Figure 3-9 [16], assuming both the caller and the callee have the same home network. This procedure starts when the IMS user agent sends a SIP INVITE message with the Request-URI of the TEL-URI format. Upon receipt of the INVITE message, the S-CSCF contacts an Electronic Number (ENUM) server in order to convert the destined TEL URI into a routable SIP URI. If the TEL URI is not stored in the ENUM Server (indicating the callee is not an IMS user), the S-CSCF will forward (via the Mi interface) the INVITE message to a BGCF, which determines the breakout should occur in the same network for this example. The BGCF selects an MGCF and forwards the INVITE message via the Mj interface. The MGCF first demands the IM-MGW to allocate media resource for the IMS user, and then sends a corresponding ISUP IAM message to the SGW using the M3UA as the transport. The same message is sent to the SS7 network from the SGW but using the MTP3 as the transport. After the IAM message is delivered to the SS7 network, ACM and ANM messages are normally returned to the MGCF, which sends to the IMS users the corresponding 180 ringing and 200 OK messages. Note that when the IMS user receives a provisional response (e.g., SIP 180 or 183), the user will return a SIP PRACK message in order to reliably acknowledge the response.

3.4 IMS charging Architecture

The IMS supports both offline charging (postpaid) and online charging (real-time prepaid) services. Figure 3-10 shows the IMS charging architecture, where two types of application servers in the IMS service layer are provided to support charging functions [6][7]. These include the Charging Collection/Data Function (CCF in Release 5, CDF in Release 6) for the postpaid service and the Online Charging Function (OCF) for the real-time prepaid service. The addresses of these charging functions can be configured locally in IMS elements or be obtained from the P-Charging-Function-Addresses header carried in SIP messages.

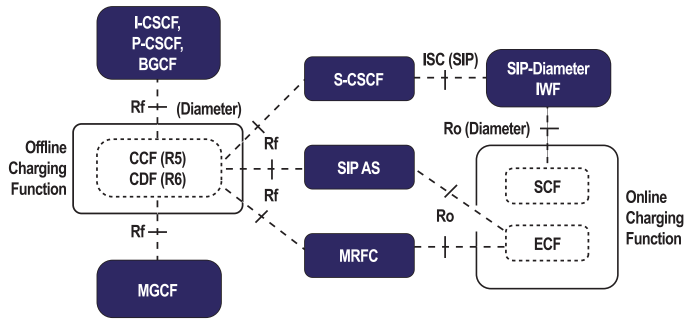


Figure 3-10 IMS Charging Architecture

As shown in Figure 3-10, the IMS elements interfacing with the CCF/CDF via this interface include the P-CSCF, I-CSCF, S-CSCF, BGCF, and MGCF. The offline-charging interface to these elements is the Diameter accounting-based Rf interface [9][15]. The CCF/CDF is a stateless Diameter AS, which does not maintain session states but only transaction states. Depending on received signaling messages, an IMS element will send the CCF/CDF a corresponding Diameter Accounting Request (ACR) message for start, interim, stop, and event of accounting operations. The CCF/CDF creates or updates CDRs based on these accounting messages. As an example, Figure 3-11 shows an offline charging message flow between a CSCF and a CCF/CDF during the lifecycle of a session. In this procedure, an ACR-start is triggered upon receipt of a 200 OK (for an INVITE) message, an ACR-interim is sent upon expiration of the interim duration (specified in the interval AVP), and an ACR-stop is triggered upon receipt of a BYE message for the session.

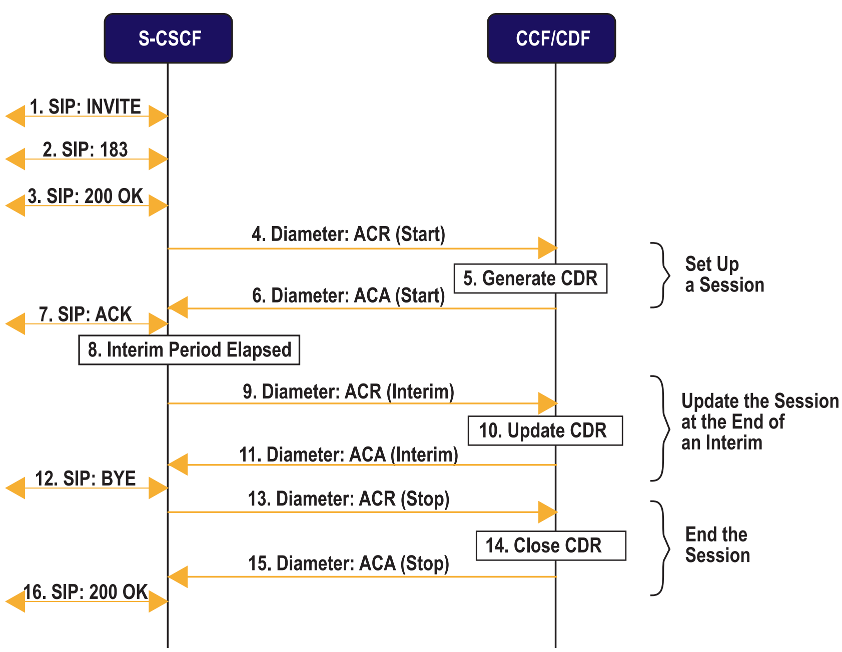


Figure 3-11 Signaling Flow for a Session-Based Offline Charging

The online-charging interface (or Ro interface) is an extension to the IETF Diameter Credit Control Application [9][17]. As shown in Figure 3-10, the IMS elements interacting with the OCF via this interface include the S-CSCF, SIP AS, and MRFC. The S-CSCF interacts with the Session Charging Function (SCF) of the OCF for session-based prepaid service control, while the SIP AS and the MRFC interact with the Event Charging Function (ECF) of the OCF for content-based prepaid control. There exists a SIP and Diameter Interworking Function (IWF) between the S-CSCF and the SCF, which maps signaling messages between SIP and Diameter. This SIP-Diameter IWF may be a standalone entity or be collocated with the S-CSCF. NOTE: This IWF is not currently standardized in the 3GPP.

The OCF is a stateful Diameter AS, which maintains both session states and transaction states. Depending on the received SIP messages and the service usage condition, a credit control client (e.g., SIP-Diameter IWF) will send Diameter Credit-Control-Request (CCR) messages to the OCF for allocating or returning (unused) monetary units or non-monetary service units (e.g., volume, duration). Depending on a subscriber's account balance, the OCF returns corresponding Credit-Control-Answer (CCA) messages for granting service units or rejecting the request. As an example, Figure 3-12 shows a session-based online charging message flow (NOTE: This message flow is not from a standard document, but is created by the author). During this control procedure, the IWF maintains interworking state models and sends out Diameter messages based on current states and received SIP messages. More specifically, it sends the SCF a CCR-Initial-Request upon receipt of a SIP INVITE message, a CCR-Update-Request when granted service units are going to be depleted, and a CCR-Termination-Request upon receipt of a SIP BYE message for the session. It should be noted that when interacting with the SIP-Diameter IWF, the S-CSCF acts as a proxy and forwards all the received SIP messages, while the SIP-Diameter IWF in turn routes the same message back to the S-CSCF after necessary trigger point processing.

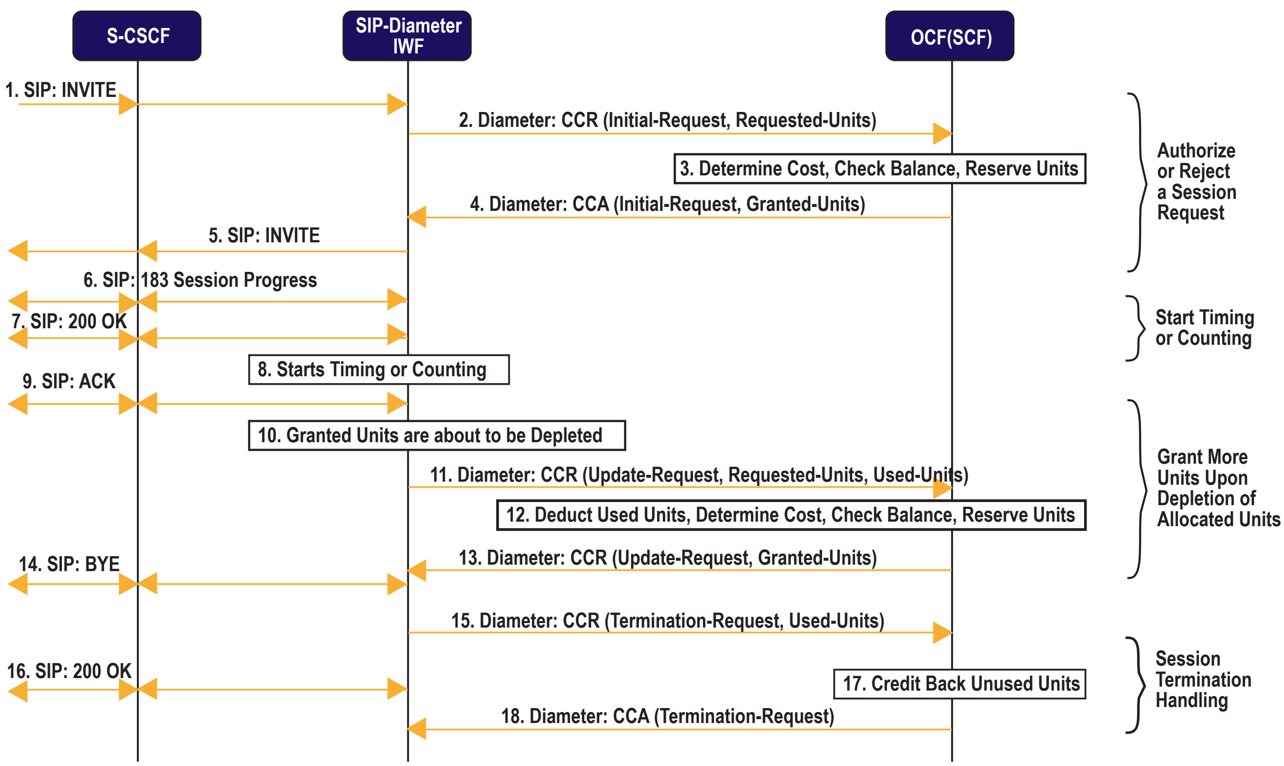


Figure 3-12 Signaling Flow for a Session-Based Online Charging

Section 4

4. IMS Signaling Gateways

The progress towards IMS-based all-IP networks is evolutionary. For the foreseeable future, communication networks will cohabitate in a heterogeneous environment comprised of fixed and mobile, CS and PS networks. There will be a variety of network interworking scenarios that require different types of signaling gateways. In general, signaling gateways will be needed for the following purposes:

- Support roaming between IMS and CS networks with gateways such as IMS-GSM Mobility Gateway
- Support IMS and CS interworking with gateways such as Signaling Transport (SIGTRAN) Gateway and SIP-Short Message Service (SMS) Gateway
- Leverage or reuse legacy mobile IN infrastructures and databases with gateways such as SIP-to-CAP Gateway and SIP-to-TCAP Gateway

The following subsections introduce a number of signaling gateways for various deployment environments and usage scenarios.

4.1 IMS Mobility Gateway

A user with a dual-mode handset capable of receiving either a 2.5G GSM service or an IMS service (e.g., using a WLAN network as the access) may roam between GSM networks and IMS networks. Similar services can also be provided for a CDMA device. To support such a roaming service, an IMS-GSM Mobility Gateway is needed when the dual mode user's HLR and HSS are not collocated. Figure 4-1 shows a network architecture with such a gateway deployed on network borders. In this architecture, the IMS-GSM Mobility Gateway acts as a VLR (via the D interface) from the perspective of a Mobile Switching Center (MSC)/VLR, as an AS (via the Sh interface) from the perspective of an HSS, and as an AS (via the ISC interface) from the perspective of an S-CSCF.

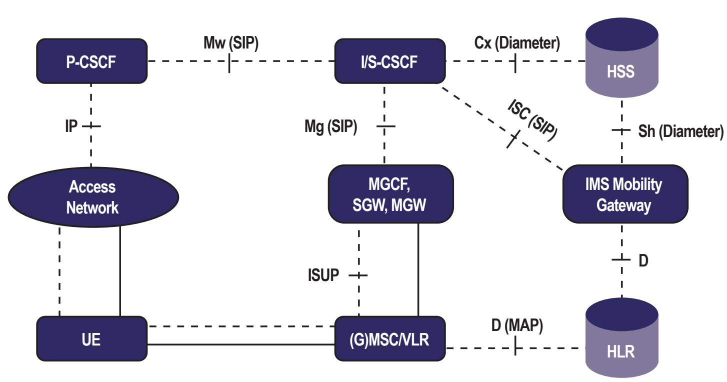


Figure 4-1 IMS Mobility Gateway for Dual-Mode Users Roaming between IMS and GSM Networks

This gateway, in fact, comprises a SIP-MAP Gateway function and a MAP-Diameter Gateway function. The SIP-MAP Gateway function allows a dual-mode user to register with the HSS and deregister with the current Visited Location Register (VLR) when the user roams from the GSM network to the IMS network. On the other hand, it allows the user to register with a VLR and deregister with the HSS when the user roams from the IMS network to the GSM network. To describe the SIP-MAP Gateway function, a message flow for a dual-mode user who roams from a GSM network to an IMS network is given in Figure 4-2. Upon user registration with the IMS network, the S-CSCF sends a SIP REGISTER message to the IMS-GSM Gateway, which in turn sends a MAP Update Location message to the HLR. The HLR treats the Gateway as another VLR; therefore, it deregisters the user from the current VLR via a MAP Cancel Location message.

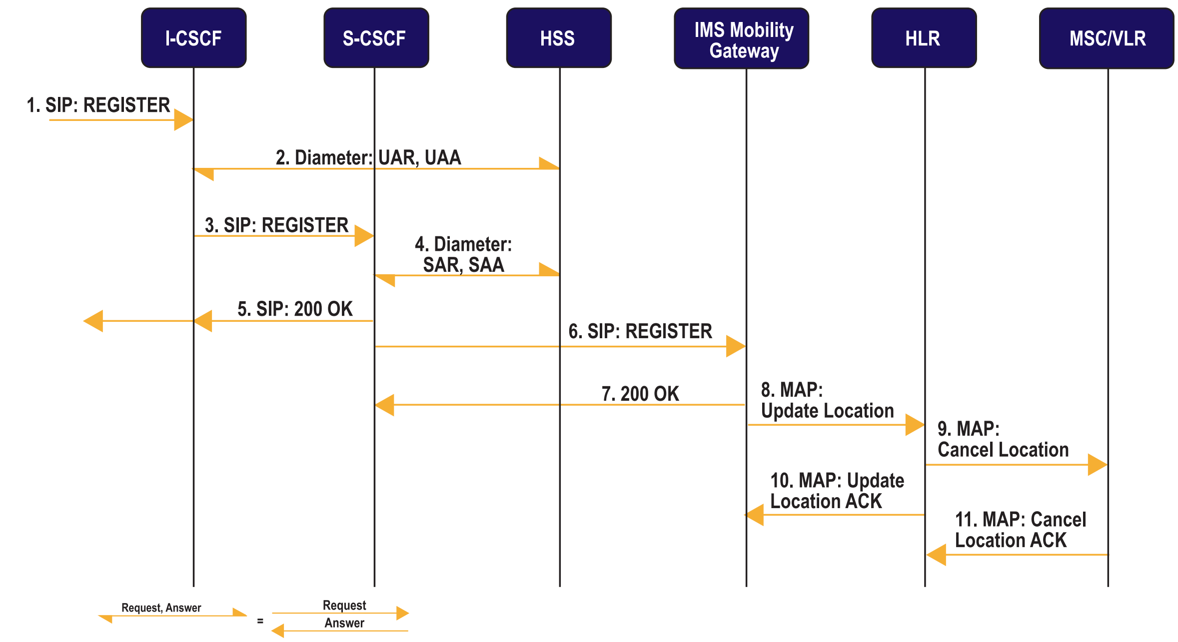


Figure 4-2 Message Flow of a Dual-Mode User Roaming from a GSM to an IMS Network

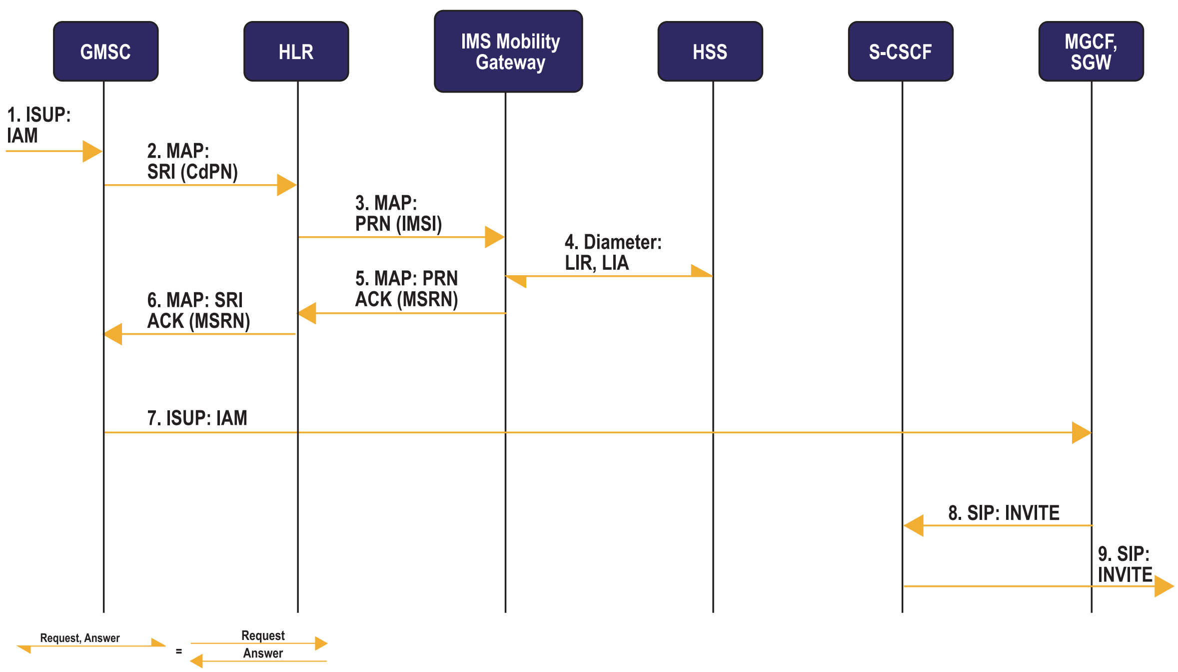


Figure 4-3 Message Flow of a CS User Calling an IMS User

The MAP-Diameter Gateway function allows the HLR and the HSS to query each other for the user's location information. To understand this function, a message flow is given in Figure 4-3. This flow assumes a call is originated from a CS user and is destined for an IMS user. Following a mobile termination procedure, the terminating Gateway MSC (GMSC) requests from the HLR the called user's Mobile Station Roaming Number (MSRN) via a Subscriber Roaming Information (SRI) message. The HLR considers the IMS-GSM Gateway as a VLR; therefore, it contacts the Gateway for the MSRN via a MAP Provide Roaming Number (PRN) message. The Gateway knows that the called user is in the IMS according to the response

from the HSS, and returns an MSRN. The GMSC then routes the ISUP IAM message to the MGCF, which sends out a corresponding SIP INVITE message.

4.2 SIP-to-TCAP Gateway

In traditional SS7 networks, SCPs are deployed to support TCAP-based database query applications such as toll-free numbers, Caller Name (CNAM), and Local Number Portability (LNP). These existing SCPs may be leveraged to provide legacy SS7 applications. A SIP-to-TCAP Gateway or border element is needed to bridge SIP and TCAP messages between an IMS element (e.g., S-CSCF) and an SCP. The gateway acts as a redirect agent from the perspective of the IMS element, and as an SSF from the perspective of the SCP.

As an example, Figure 4-4 shows a message flow for a toll-free number translation application through a SIP-to-TCAP Gateway. An S-CSCF sends to the gateway an INVITE message containing a toll-free number (TEL URI), which is then translated into a routable telephone number through an SCP. The gateway returns a SIP 302 Moved Temporarily message to the S-CSCF, which contains the translated number. The IMS user that originates the initial INVITE message will send another INVITE with the translated number as the destination address.

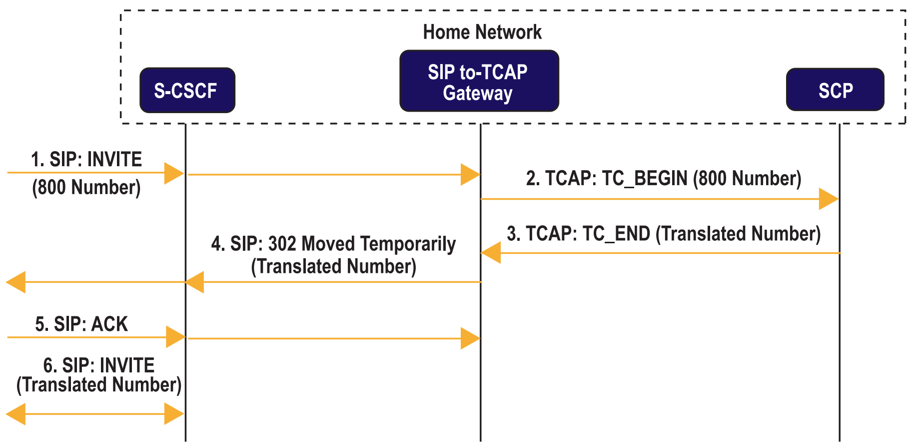


Figure 4-4 Message Flow of a Toll-Free Number Application through a SIP-to-TCAP Gateway

4.3 SIP-to-CAP Gateway

Legacy CAMEL network infrastructure supports mobile IN services such as prepaid charging, Wireless Number Portability (WNP), Caller Name (CNAM) presentation, and so on. In order to leverage CAMEL infrastructure and cost effectively provide IMS users with those mobile IN services, an IM-SSF can be deployed between an S-CSCF and an SCP [10]. The IM-SSF is, in fact, a SIP-to-CAP gateway that provides interworking functions between SIP session control and the CAMEL Application Part (CAP) state models. On the one hand, it interacts with an S-CSCF via the ISC interface and acts as a SIP AS. On the other hand, it interacts with an SCP via the CAP interface and acts as an SSF. The IM-SSF can be a standalone entity or a function integrated into an S-CSCF.

The working scenario of the IM-SSF is as follows. During user registration, it downloads triggering point information from the HSS/HLR through the MAP-based Si interface (see Figure 3-4), and arms IM Basic Call State Models (IM-BCSMs) accordingly. During the lifecycle of a SIP session, the IM-SSF maintains an originating or a terminating IM-BCSM and conducts service control. That is, based on armed trigger points in an IM-BCSM, the IM-SCF sends CAP requests to the SCP upon receipt of triggering SIP messages from the S-CSCF. As an example, Figure 4-5 illustrates a message flow for an online charging (prepaid) control procedure. In addition to CAP, SIP may be able to interwork with other TCAP-based IN protocols (based on the same principle), such as Intelligent Network Application Part (INAP) and Advanced Intelligent Network (AIN).

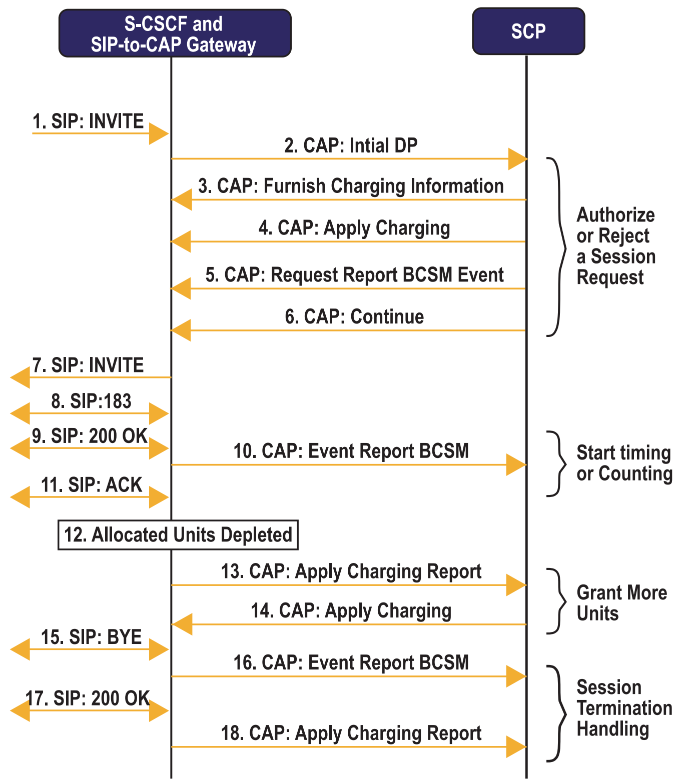


Figure 4-5 Message Flow of Online Charging Control with SIP-to-CAP Gateway

4.4 SIP-to-SMS Gateway

SMS, which is carried over MAP protocol, is one of the most successful mobile services provided via SS7 networks. A similar messaging service is supported via IMS networks as well. IMS-based messaging includes a pager mode service and a session mode service. The pager mode is used to send text messages with a limited size, which corresponds to SMS, while the session mode is used to send multimedia messages, and needs to transfer messages within an established session.

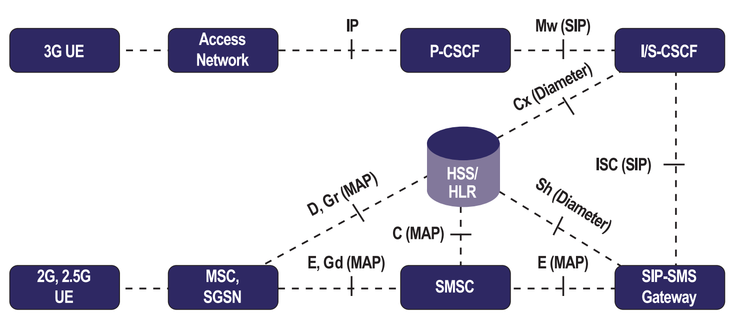


Figure 4-6 Interworking Architecture of SIP and SMS

When an SMS user and an IMS user exchange short messages, a SIP-SMS Gateway is needed. This paper proposes the network architecture with a SIP-SMS Gateway for bridging SIP and SMS messages as shown

in Figure 4-6. In this architecture, the SIP-SMS Gateway acts as an MSC from the perspective of an SMS Center (SMSC), and as a SIP AS from the perspective of an S-CSCF and from the HSS/HLR. As an example, Figure 4-7 shows a message flow with an SMS user sending a short message to an IMS user. In order for the HSS/HLR to know the Gateway address, upon IMS user registration, the Gateway needs to inform the HLR of its address via the Diameter-based Sh interface (as shown in step 4).

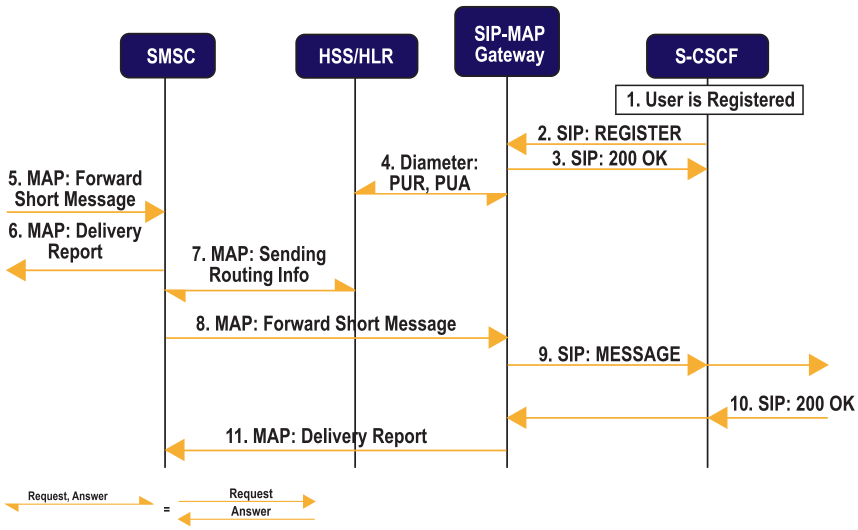


Figure 4-7 Message Flow of an GSM User Sending a Short Message to an IMS User

Section 5

5. IMS-Ready Signalware Platform

IMS plays a pivotal role in the convergence of wireless and fixed networks. Ulticom's IMS-Ready™ Signalware products are in the forefront to support signaling network elements in IMS-based, converged networks. Ulticom is well positioned to provide a carrier-grade, IMS service-enabling, signaling middleware platform.

Signalware is an industry-proven, carrier-grade, highly available, and modularly scalable signaling application development and execution platform. It provides a rich suite of signaling protocol offerings and a reliable system development and execution environment. Figure 5-1 illustrates the Signalware IMS platform architecture; the shaded components are available from Ulticom today.

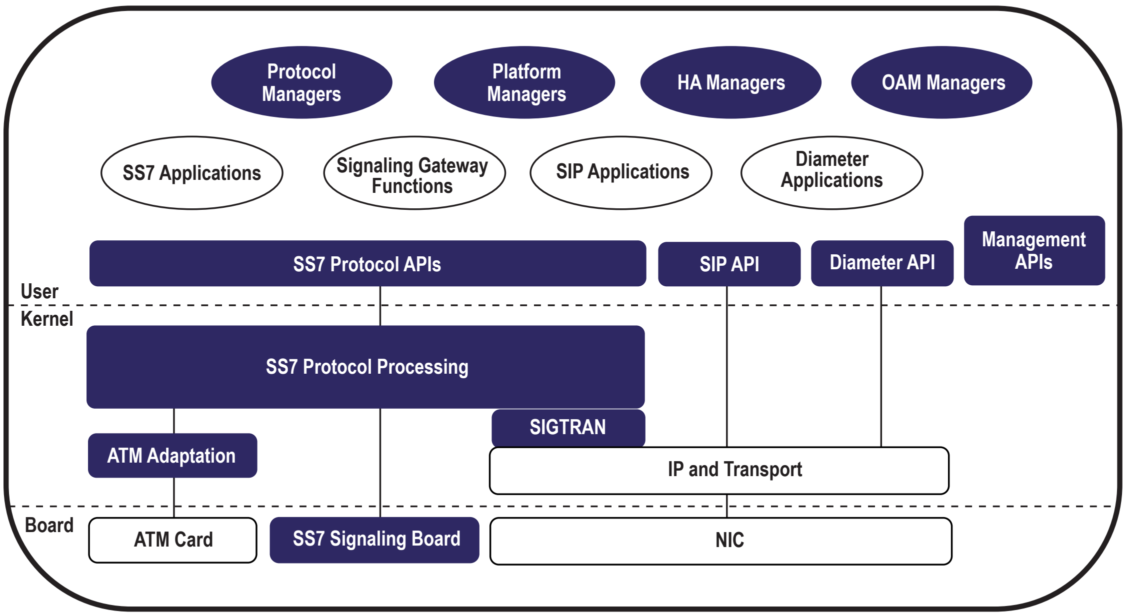


Figure 5-1 IMS-Ready Signalware Platform Architecture

As shown in the architecture, Signalware supports a full range of signaling protocols, including:

- **SIP**, for which Signalware SIP supports both specifications defined in the Internet Engineering Task Force (IETF) and private extensions defined in the 3rd Generation Partnership Project (3GPP).
- **Diameter**, for which Signalware Diameter supports Diameter base protocol and various Diameter applications.
- **SS7** protocols, for which Signalware SS7 provides a full range of SS7, SS7/IP, and SS7/ATM protocols. Furthermore, Signalware supports a wide range of global standards and national variants.

These protocols interface with applications using Signalware APIs. Detailed protocols offered by Ulticom are depicted as shaded areas in Figure 5-2. Note that Signalware uses operating system features (e.g., IPsec, provided in the OS to enable security protection. With these signaling protocols and management environment, IMS-Ready Signalware enables virtually all the signaling servers and gateways essential to IMS-based fixed and mobile converged networks. These include SIP servers, Diameter servers, signaling gateways, and associated interfaces. A table in Appendix A summarizes the IMS elements and interfaces that the Signalware platform supports.

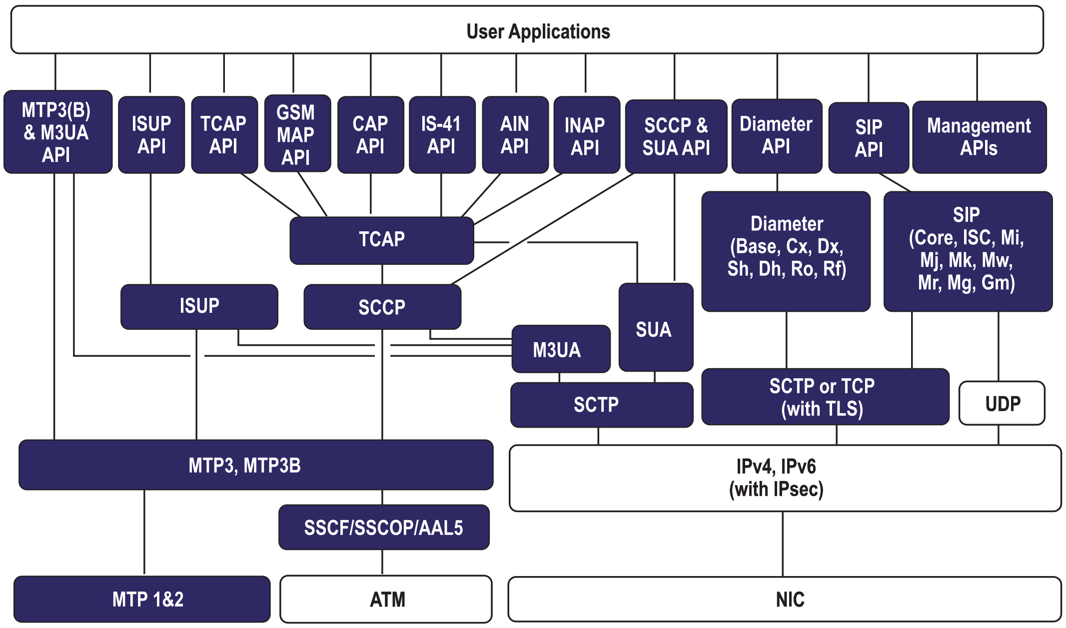


Figure 5-2 Signaling Protocols Offered in Signalware Platform

Benefits of IMS-Ready Signalware

IMS-Ready Signalware offers the following advantages and benefits, which are critical to NEPs and carriers in order to successfully deploy IMS networks and services :

- Rapid time to market, which allows faster, more cost-effective development and deployment of IMS networks and services with Signalware APIs, sample applications, and Ulticom's professional services.
- Fault resilience, which ensures high availability (99.999%) of systems and services, and prevents revenue loss from down time. This level of availability is not only provided in traditional Signalware SS7-backed network elements, but also is ensured for IP-based signaling elements backed by Signalware SIP, Diameter, or combinations of Signalware SS7-based and IP-based signaling protocols. To achieve this, both hardware and software components (e.g., computing elements, software processes, network connectivity, and signaling boards) are redundant and actively monitored. Upon failure of one component, its backup component takes over in a timely manner.
- Scalability, which enables modular increase of system capacity in order to meet different application and deployment needs. Signalware supports a cluster containing one to four Computing Elements (CEs). In order to hide server infrastructure, Signalware provides virtual IP features, which present a single server image to external signaling networks.
- Portability, which facilitates systems to be ported across different operating system-based platforms (e.g., Solaris, Linux).
- Network interoperability, which enables interworking between different types of networks (e.g., between SS7 networks and SIP networks) and between different protocol variants (e.g., between 3GPP SIP and other SIP variants). As Signalware provides a full-fledged, hybrid, carrier-grade signaling platform, network interoperability is more easily achieved.
- Maintainability, which facilitates Operations, Administration and Maintenance (OAM), and lowers cost of network ownership. Signalware OAM functions include provisioning, event logging, measurement collection, and platform management using Man Machine Language (MML), Graphical User Interface (GUI), and Simple Network Management Protocol (SNMP)-based remote access.

Appendix A

References

[1] 3GPP TS 22.228, "Service requirements for the Internet Protocol (IP) multimedia core network subsystem", release 7.

[2] 3GPP TS 23.228, "IP Multimedia Subsystem (IMS)", release 6.

[3] 3GPP TS 23.002, "Network architecture", release 6.

[4] 3GPP TS 32.260, "IP Multimedia Subsystem (IMS) charging", release 6.

[5] 3GPP TS 29.228, "IP Multimedia (IM) Subsystem Cx and Dx interfaces, Signaling flows and message contents", release 6.

[6] 3GPP TS 24.229, "IP Multimedia Call Control Protocol based on SIP and SDP", release 6.

[7] 3GPP TS 32.225, "Charging data description for the IP Multimedia Subsystem (IMS)", release 5.

[8] 3GPP TS 23.234, "3GPP system to Wireless Local Area Network (WLAN), System Description", release 6.

[9] 3GPP TS 32.299, "Diameter charging applications", release 6.

[10] 3GPP TS 23.278, "CAMEL IM CN Interworking, Phase 4, Stage 2", release 6.

[11] 3GPP2 X.S0013, "All-IP Core Network Multimedia Domain: Overview", December 2003.

[12] ETSI TISPAN, "Converged Fixed-Mobile solutions: The TISPAN NGN approach", presentation slides, November 2004.

[13] OMA, "Push-to-Talk over Cellular (PoC) Architecture", release 2.0, June 2004.

[14] IETF RFC 3261, "Session Initiation Protocol (SIP)", June 2002.

[15] IETF RFC 3588, "Diameter Base Protocol", September 2003.

[16] 3GPP TS 24.228, "Signaling flows for the IP multimedia call control based on SIP and SDP", Release 6.

[17] IETF Draft, "Diameter Credit Control Application", draft-ietf-aaa-diameter-cc-06.txt, Aug. 2004.

[18] IETF RFC 3320, "Signaling Compression (SigComp)", January 2003.

Appendix B

Signaling Interfaces

IMS Group	Network Element	Interface	Protocol
IMS Core	S-CSCF	Cx (HSS)	Diameter Cx Application
		Dx (SLF)	Diameter Dx Application
		Mw (CSCF)	SIP
		ISC (AS, Gateways)	SIP
		Mr (MRFC)	SIP
		Mg (MGCF)	SIP
		Ro (CCF, CDF), optional	Diameter Charging Application
		Rf (OCF)	Diameter Charging Application
		(ENUM Server)	DNS
	P-CSCF	P-CSCF Mw (I/S-CSCF)	SIP
		Gm (UE)	SIP, SigComp
		Ro (CCF, CDF)	Diameter Charging Application
		Gq (PDF)	Diameter Gq Application
	I-CSCF	Cx (HSS)	Diameter Cx Application
		Dx (SLF)	Diameter Dx Application
		Mw (P/S-CSCF)	SIP
		Ro (CCF, CDF)	Diameter Charging Application
	HSS	Cx (I/S-CSCF)	Diameter Cx Application
		Sh (AS)	Diameter Sh Application
	SLF	Dx (I/S-CSCF)	Diameter Dx Application
		Dh (AS)	Diameter Dh Application
IMS Service Delivery	SIP AS	ISC (S-CSCF)	SIP, SIMPLE
		Sh (HSS)	Diameter Sh Application
		Dh (SLF)	Diameter Dh Application
		Ro (CCF, CDF)	Diameter Charging Application
		Rf (OCF)	Diameter Charging Application
	OSA SCS	ISC (S-CSCF)	SIP
		Sh (HSS)	Diameter Sh Application
		Dh (SLF)	Diameter Dh Application
	MRFC	Mr (S-CSCF, IM-SSF)	SIP

IMS Group	Network Element	Interface	Protocol
IMS Core	MRFC	Ro (CCF, CDF)	Diameter Charging Application
		Rf (OCF)	Diameter Charging Application
IMS-SS7 (CS) Interworking	BGCF	Mi (S-CSCF)	SIP
		Mj (MGCF)	SIP
		Mk (BGCF)	SIP
		Ro (CCF, CDF)	Diameter Charging Application
	MGCF	Mj (BGCF)	SIP
		(SGW)	ISUP/M3UA
		Ro (CCF, CDF)	Diameter Charging Application
	SGW	(MGCF)	ISUP/M3UA
		(CS, PSTN)	ISUP/SS7
	HLR	Si (IM-SSF)	MAP
		D (SIP-MAP GW, SIP-SMS GW)	MAP
	SIP-CAP Gateway (IM-SSF)	Si (HLR)	MAP
		ISC (S-CSCF)	SIP
		Mr (MRFC)	SIP
		(SCP)	CAP
	IMS-GSM Gateway	ISC (S-CSCF)	SIP
		Sh (HLR)	Diameter Sh Application
		E' (HLR)	MAP
	SIP-TCAP Gateway, SIP-IN Gateway	ISC (S-CSCF)	SIP
		(SCP)	TCAP, INAP, AIN
	SIP-SMS Gateway	ISC (S-CSCF)	SIP, SIMPLE
		Sh (HLR)	Diameter Sh Application
		E' (SMSC)	SMS/MAP
IMS Charging	OCF	Ro (SIP-Diameter IWF, SIP AS, MRFC)	Diameter Charging Application
	CCF, CDF	Rf (P/I-S-CSCF, BGCF, MGCF, SIP AS, MRFC)	Diameter Charging Application
	SIP-Diameter IWF	Ro (OCF)	Diameter Charging Application
		ISC (S-CSCF)	SIP

Appendix C

Terms and Acronyms

Acronym	Description
25G	2.5th Generation
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
AAA	Authentication, Authorization and Accounting
AIN	Advanced Intelligent Network
API	Application Programming Interface
AS	Application Server
ATM	Asynchronous Transfer Mode
AuC	Authentication Center
AVP	Attribute-Value-Pairs
B2BUA	Back-To-Back UA
BCSM	Basic Call State Model
BGCF	Breakout Gateway Control Function
CAMEL	Customized Applications for Mobile network Enhanced Logic
CAP	CAMEL Application Part
CCF	Charging Collection Function
CDF	Charging Data Function
CDMA2000	Code Division Multiple Access 2000
CDR	Charging Data Record
CE	Computing Element
CNAM	Caller Name
COPS	Common Open Policy Service
CS	Circuit-Switched
CSCF	Call Session Control Function
DNS	Domain Name Server
DSL	Digital Subscriber Line
ECF	Event Charging Function
ENUM	Electronic Numbering
ETSI	European Telecommunications Standards Institute
GGSN	Gateway GPRS Support Node

GMSC	Gateway MSC
GPRS	General Packet Radio Services
GSM	Global System for Mobile communication
HLR	Home Location Register
HSS	Home Subscriber Server
HTTP	Hyper Text Transfer Protocol
I-CSCF	Interrogating CSCF
IETF	Internet Engineering Task Force
IM	Internet Multimedia
IMS	Internet Protocol Multimedia Subsystem
IMSI	International Mobile Subscriber Identifier
INAP	Intelligent Network Application Part
IP	Internet Protocol
IPsec	IP Security
ISC	IP Multimedia Service Control
ISUP	ISDN User Part
IWF	Interworking Function
LNP	Local Number Portability
M3UA	MTP3 User Adaptation Layer
MAP	Mobile Application Part
Megaco	Media Gateway Control Protocol
MGCF	Media Gateway Control Function
MGW	Media Gateway
MMD	Multimedia Domain
MML	Man Machine Language
MRF	Media Resource Function
MRFC	Media Resource Function Controller
MRFP	MRF Processor
MSC	Mobile Switch Center
MSRN	Mobile Subscriber Roaming Number
NEP	Network Equipment Provider
OCF	Online Charging Function
OCS	Online Charging System
OMA	Open Mobile Alliance
OSA	Open Service Access
P-CSCF	Proxy CSCF

PDF	Policy Decision Function
PDSN	Packet Data Serving Node
PoC	Push-to-Talk over Cellular
PS	Packet-Switched
PSTN	Public Switched Telephone Network
RAN	Radio Access Network
RTP	Real-Time Transport Protocol
CSCF	Serving Call State Control Function
SCF	Session Charging Function
SCIM	Service Capability Interaction Manager
SCP	Service Control Point
SGW	Signaling Gateway
SCTP	Stream Control Transmission Protocol
SGS	Signaling Gateway
SigComp	Signaling Compression
SIGTRAN	Signaling Transport
SIP	Session Initiation Protocol
SLF	Subscription Locator Function
SMS	Short Message Service
SMSC	SMS Center
SNMP	Simple Network Management Protocol
SS7	Signaling System No. 7
SSF	Service Switching Function
TCAP	Transaction Capability Application Part
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
TLS	Transport Layer Security
UA	User Agent
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
URI	Uniform Resource Identifier
VLR	Visited Location Register
VPN	Virtual Private Network
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WNP	Wireless Number Portability